To meet the Sustainable Development Goals, we must transform innovation

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In 1925, Mahatma Gandhi famously included 'science without humanity' and 'knowledge without character', alongside 'politics without principle' and 'commerce without morality' in listing Seven Social Sins. Today, we can see these social sins of Modernity as central to unsustainability, ranging from climate disruptions and toxic wastes, to rampant inequality and poverty.

The United Nations (UN) Sustainable Development Goals (SDGs) are arguably the most comprehensive modern attempt to tackle unsustainability challenges. Yet it remains to be seen if they can deliver the ambitious *transformations* in science, technology, politics and commerce needed to avoid reproducing Gandhi's compellingly diagnosed syndromes – and so achieve genuine sustainability.

While the "development, transfer and dissemination" of relevant sciences, technologies and innovations (STIs) is central to the UN's 2030 Agenda for transforming our world, the need to transform incumbent structures governing the development of modern science and technology is left largely out of the picture. Meanwhile, transformative social and political innovations are

The UN promotes the following STIs as relevant for the SDGs: modern energy generation and distribution infrastructures; pharmaceutical innovations; agricultural and marine technologies for environmental monitoring; and information and communication technologies for bridging the "digital divide" (SDG 10). STIs such as these, are argued to enable "gender equality" (SDG 5), "quality education" (SDG 4), "climate resilience" (SDG 13), "sustainable industrialisation" (SDG 12) and the overall acceleration of "human progress" through economic growth (SDG 8).

The 17 UN Sustainable Development Goals

But what if dominant modern pathways of STI development, transfer and dissemination, across energy, agriculture, ICT, mining, transportation and manufacturing (of toxics), are widely mismatched with the majority of SDG priorities? Clearly, if dominant STI pathways were actually well-aligned with the SDGs, the UN's list of "immense challenges" might *not* have included poverty, climate change, environmental degradation, loss of biodiversity, and rising inequality.

In any given area of activity (viewed across many countries), it is repeatedly the case that just one (or two) STI pathway(s) can typically be observed to dominate. For example, in transport the dominant STI pathway may be seen as comprising privately owned fossil-fuelled automobiles, manufacturing firms, infrastructure of roads and fuelling stations, and regulations for speed and pollution control. In information-communication, the dominant pathway is constituted by silicon microchip-based computing (also in smartphones and tablets), fibre-optic and copper cabling, a network of servers running with the world wide web, tech corporations, regulations and international conventions for managing electronic waste, and government attempts to filter content (communicated over the internet).

For sustainability, it is crucial to transform each dominant STI pathway from within. For example, through innovation and regulation for 'cleaner production', aimed at reducing the pathway's negative impacts on societies and the environment. Equally crucial for sustainability, however, are deeper transformations to recognise and promote a diversity of STI pathways.

A diversity of pathways

be approached as embedded within wider social, ecological and technical *pathways*. This characterises innovations as socio-ecological processes rather than outputs.

The idea of STIs as pathways (rather than artefacts) allows researchers to map the dynamism and diversity inherent to STIs and the wider social and ecological developments in which they are embedded. Crucially, it involves understanding innovation systems in their broadest and most holistic sense – including science and technology, but also deeply co-evolving institutional, cultural and ecological change.

This short animation from the ESRC STEPS Centre introduces the idea of *pathways to sustainability*.

Pathways emphasise that what matters in any given area of activity is not just the general pace of advance, or the costs and benefits associated with specific STIs, but also the particular direction of change.

For example, in food production systems, dominant existing directions focus on modern technological innovations like 'precision agriculture' using artificial intelligence and data analytics, genetically modified seeds, insect growth regulators to stop the development of cuticles or exoskeletons in 'pests', and micro-organisms as fertilisers. Alternative directions may be based on agroecological techniques such as mulching, rainwater harvesting, and farm-saving seed varieties that are adapted to local soil and climatic conditions and potentially resilient to disruptions such as droughts and floods.

framings. So, while the dominant agricultural pathway may frame problems as narrowly technical (e.g., focused on making synthetic fertilisers more sustainable or more productive), agroecological pathways are often oriented by framings of problems as complex tangles of social and environmental issues (e.g., groundwater depletion and associated vulnerability of smallholder livelihoods).

A pathway becomes dominant or incumbent by aligning framings, shaping policies, accumulating knowledges, growing investments, controlling resources, layering technologies, homogenising standards, and structuring hierarchies. As these dynamics unfold, the overall process of pathway-building can become self-reinforcing.

Consider STI pathways to address conflicts around overfishing, as mapped in the Lake Victoria region (a case study in our STRINGS project). One STI pathway may be structured around community-based monitoring of overfishing, with supporting policies to protect and promote local fishers' livelihoods and networking activities. This pathway thus foregrounds small fishers who are often marginalised in policy circles. It has the potential to reduce poverty and inequality while caring for life under water.

An alternative pathway may rely on modern monitoring and surveillance techniques, deployed particularly by governments to keep industrial trawlers from fishing beyond their quotas and to eliminate the so-called bycatch. This pathway may be aligned with policies to promote economic growth through industrialisation of fishing (often for export markets). It may also be buttressed by economic policy framings of employment generation in an industrialised fishing sector.

Thus, to address any socio-ecological issue – as defined in any given SDG or one of its targets – *diverse* STI pathways are available or possible.

It is crucial to note, however, that an 'STI pathway' is a concept that should not be equated to some actually existing reality. Depending on how the idea is used by different researchers – with the help of specific research methods and analytical techniques and grounding assumptions – a plurality of equally reasonable perspectives can be developed on the 'same' pathway.

A plurality of perspectives

There can never be a single, self-evident – let alone definitive – mapping of any pathway. This

as salient, whilst downplaying others. Highlighting any specific process or relation among the multitude that are relevant will sadly always relatively marginalise others.

For example, consider the work of smallholders and civil society organisations conserving and developing 'traditional' stress-tolerant varieties of rice studied in another STRINGS case study, supporting more resilient and equitable food provision in Odisha, India. Depending on the methods used, plural perspectives can be revealed on this pathway.

Rice farming in India. Photo by Deepak Kumar on Unsplash.

Using ethnographic methods of detailed conversations and participation in seed growing and sharing, the mapping produced of this pathway may highlight the work of a particular assemblage of actors and materials. The skills and knowledges for selecting plants for picking seeds, and subsequent cleaning and drying techniques can be shown to be distributed in this assemblage.

A contrasting perspective on the 'same' pathway may be produced using semi-structured interviews with 'key informants' and document analysis. Here, a network of seed-saving farmers and civil society organisations may be brought to the fore. Actors in this network try to attract resources to support the growing and distribution of seeds; test 'traditional' seeds to detect vitamin or iron content for acceptance in policy and academic communities; and promote seed kits using onsite demonstrations to farmers.

Beyond the community of researchers mapping STI pathways, other actors can also provide

'traditional' seeds in resource-constrained environments. Smallholders will also typically appraise the effectiveness of their pathway using different criteria than those used by actors such as agricultural scientists.

This is of course a reflection of the ever-present truth that there is no phenomenon, entity or process so self-evidently or concretely 'real' (and this includes an 'STI pathway'), that the ways in which it is constituted (by people, policies, knowledges and materials) cannot be framed differently under contrasting perspectives.

It is therefore all the more essential and pragmatic to recognise that this is also true for appraisals of contrasting STI pathways in any particular setting – and how they might be held to 'align' or 'misalign' with the many values and objectives embraced in the SDGs.

Mappings of misalignments

Plural perspectives on alignments and misalignments between STIs and SDGs is one key strand in STRINGS. To this end, at 'global' and 'national' levels, in select fields, the project searches for relevant material in available databases of scientific publications and patents by means of a keyword-based scientometric approach.

This approach entails the use of data-mining techniques on a wide range of documents, to identify a set of 'keywords' that are closely associated with the SDGs. The keywords are then used to search through Web of Science (WoS) publications in 4013 research areas. WoS publications are clustered into research areas using citation relations between them.

Using these 'content mapping' techniques, we are producing visualisations of how different 'global' and 'national' STI pathways relate to the SDGs under particular framings. Of course, the framings of pathways, and of values and priorities as embodied in the SDGs, elicited will be those that happen to be most evident in the data.

Therefore, in order to be similarly systematic about the expert communities associated with producing this data, we are also undertaking a large-scale Delphi survey. This involves a structured response from a large number of experts, from across as many dimensions of relevance as possible.

The aim of the Delphi survey is to gain as clear a picture as possible of the plurality of views in different practitioner communities, on the sustainability potentials of contrasting STI pathways, and on the ways in which these relate to contrastingly prioritised visions of the SDGs.

In this way, the scientometric approach and the Delphi survey offer ways to explore diversities of STI contexts and pluralities of perspectives on these contexts.

Of course, both scientometric approach and Delphi interactions will contribute to the plurality of frames in focus by adding their own methodological contingencies. So, the picture given in any resulting map will not be any more comprehensive or definitive than is the qualitative mapping of STI pathways in the fishing and farming case studies discussed above.

Opening up debates

This coupling of qualitative and quantitative approaches aims at 'opening up' a plurality of maps of STI pathways in each setting. This plurality can help to address some of the questions around focus and context, which might otherwise arise around the framing of analysis itself.

Again, the point is not to claim a definitively complete or final picture, but to prompt more refined questions and so help stimulate and inform more rigorous, robust and accountable policy debates about the directions taken in STI for sustainability.

In STRINGS, then, we hope to produce insights which can help resist existing powerful pressures that close down social choice around one (or two) dominant STI pathway(s) in an area of activity. We are attempting to produce such insights in a number of independent but partly mutually reinforcing ways.

First, we are producing evidence on alignments and *misalignments* between STI pathways and the SDGs.

Second, we are attempting to illuminate a *diversity* of pathways to help address particular SDG challenges – extending attention beyond the pathways typically driven by the loudest voices and most powerful interests.

Third, we are aiming to foreground the *plurality* of perspectives that may be found – even within expert communities – on each pathway as well as on the SDGs under which they can be appraised.

	Content mapping	Delphi	Case studies

	Content mapping	Delphi	Case studies
Misalignment	Although not complete or definitive, the maps illuminate a variety of ways in which research can be seen to be misaligned with SDGs	Many elicited perspectives hold patterns of research and innovation to be misaligned with the SDGs in different ways	Each case study shows specific ways in which the STI activities in focus are mismatched with the relevant SDGs
Diversity	Across several instances, the maps show the existence of more than one research or innovation pathway towards a given SDG	Across contrasting expert perspectives (and sometimes even within a particular perspective), it often emerges that more than one STI pathway will pursue any given SDG	Each case study has identified, in some detail, a diversity of STI pathways towards the relevant SDGs
Plurality	Each possible mapping of STI onto SDGs depends, for the clarity of the picture produced, on a variety of parameters and assumptions. Even if these change only slightly (to reflect a contrasting view), details of the map	For each SDG and each broadly associated STI pathway, the Delphi survey shows there are a number a contrasting perspectives on the pros and cons of each path, and the relative merits of different pathways for addressing the	In each case study, it is clear that a variety of contrasting perspectives exist on prioritisation of relevant SDGs, as well as on the comparative pros and cons of contrasting associated STI

Table 1. Multiple methods for plural insights in STRINGS

By foregrounding diversity, plurality and misalignments, we hope to open up richer and more substantive policy debates in relation to the SDGs, both within and around existing STI governance institutions worldwide, and in wider political discourse more generally.

By building a new evidence base at the local, national and global levels, we hope to demonstrate a way to challenge the entrenched interests and expedient rhetorics that are presently slowing progress towards the SDGs.

Alongside the multiple goals of sustainability, after all, it has always been clear that process is inseparable from outcomes. With egalitarian commitment, participatory practice and emancipatory struggle for so long featuring as central to transformations towards sustainability, we trust that the more rigorous, transparent and creative kinds of questioning that may emerge from our mixed-method and interdisciplinary work can help invigorate more democratic global, national and local politics of innovation for socioecological sustainability.

Without enabling this kind of democratic politics for the steering of STI pathways, we fear the SDGs may not be met by 2030. Only by producing diverse and plural 'knowledge with character' can we hope to steer pathways to transform modern societies away from the 'social sins' identified by Gandhi.

By Louise Sheridan | April 19th, 2021 | Blogs | 0 Comments

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